

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

METHOD AND/OR SYSTEM FOR FORMING A THIN FILM

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METHOD AND/OR SYSTEM FOR FORMING A THIN FILM

BACKGROUND

Electronic devices, such as integrated circuits, solar cells, and/or electronic
5 displays, for example, may be manufactured from several material layers or films formed
on a substrate. However, techniques for forming an electronic device may be time
consuming, expensive, and/or produce inferior results.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Subject matter is particularly pointed out and distinctly claimed in the concluding
portion of the specification. The claimed subject matter, however, both as to organization
and method of operation, together with objects, features, and advantages thereof, may
best be understood by reference of the following detailed description when read with the
accompanying drawings in which:

15 FIG. 1 is a cross-sectional view of one embodiment of a device;

FIG. 2 is a schematic diagram illustrating an embodiment of a laser annealing
system; and

FIG. 3 is flowchart illustrating one embodiment of a method of forming an
embodiment of a thin film.

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DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth to provide a thorough understanding of the claimed subject matter. However, it will be understood by those skilled in the art that the claimed subject matter may be practiced without these specific details. In other instances, well-known methods, procedures, components and/or circuits have not been described in detail so as not to obscure the claimed subject matter.

Electronic devices, such as semiconductor devices, display devices, electrochromic devices, piezoelectric devices, nanotechnology devices, conductive, and/or dielectric devices, for example, may be comprised of one or more thin films, which may additionally be referred to as layers. In this context, the term thin film refers to a material formed to a particular thickness, such that particular surface properties of the material may be observed, and these properties may vary from bulk material properties, for example. These one or more layers may be further comprised of one or more materials, and the one or more materials may have particular electrical and/or chemical properties, such as a particular conductivity, particular optical properties, such as a particular transparency and/or refractive index, and/or a particular density, for example. The one or more material layers may additionally be patterned, and, in combination with one or more other patterned material layers, may form one or more electronic devices, such as thin films transistors (TFT), capacitors, diodes, resistors, photovoltaic cells, insulators, conductors, optically active devices, or the like. Thin film devices, such as TFTs, may, for example, be utilized in display devices including, for example, electroluminescent or liquid crystal displays (LCD). One particular type of patterned material layer may comprise a layer of

electrically active metal oxide, for example, and may be referred to as an oxide thin film. Depending at least in part on the type of oxide utilized to form one or more such thin films, the resultant device may comprise a transparent or semi-transparent device. Thus, an oxide thin film may be formed on a substrate, and, when formed, may be electrically
5 conductive or semiconductive, and may form a portion of an electronic device, such as the aforementioned TFT, for example.

Although the claimed subject matter is not so limited, in one embodiment of the claimed subject matter, a patterned material layer is formed by depositing a layer of
10 material on at least a portion of a substrate by use of one or more deposition processes, and selectively annealing at least a portion of the material layer by use of one or more “spot” laser annealing processes. As used herein, selectively, when used, such as with annealing, for example, generally refers to annealing one or more portions of a material, such as a layer of material, wherein the portions are selected based at least in part on the
15 particular location of the one or more portions, such as with localized or spot annealing, for example. Referring now to FIG. 1, there is illustrated an embodiment 100 of an electronic device comprising multiple layers. Embodiment 100 comprises substrate 102, and multiple material layers 104, 106, 108 and 110, as illustrated. Substrate 102 may comprise a substrate of glass, plastic, or silicon, or any combination of materials, such as
20 polyethylene terephthalate (PET) or polyethylene naphthalate (PEN). Thus, substrate 102 may comprise any material exhibiting properties suitable for application as a substrate in an electronic device.

Formed on at least a portion of substrate 102 is material layer 104, which, in this
25 embodiment, may comprise a transparent conductive oxide layer, such as indium tin oxide

(ITO), for example, although the claimed subject matter is not so limited. For example, an embodiment of a device formed in accordance with the claimed subject matter may comprise a device having multiple homogeneous and/or heterogeneous material layers, or may comprise a device comprising one material layer, for example. One or more material
5 layers may also comprise one or any combination of materials, such as metals, alloys, oxides and/or non-metal substances, including indium tin oxide, zinc tin oxide, zinc oxide (ZnO) and/or one or more organic materials such as PEDOT (Poly-3,4-Ethylenedioxythiophene), for example.

10 Continuing with this example, in this particular embodiment, formed on at least a portion of material layer 104 is an insulating material layer 106, which may comprise an oxide including aluminum titanium oxide (ATO), for example. Formed on at least a portion of material layer 106 is a dielectric material layer 108, which may comprise an oxide, such as ZnO, for example. Formed on at least a portion of material layer 108 is conductive
15 material layer 110, which may comprise an oxide including ITO, for example.

In this particular embodiment, one or more layers may be patterned. Material layer 110 may be patterned into two regions 112 and 114, for example. When assembled and in a later manufactured state, device 100 may comprise a transparent or semi-transparent
20 thin film transistor, with 102 comprising a substrate, as previously explained, material layer 104 comprising a gate, material layer 106 comprising a gate insulator, material layer 108 comprising a channel layer, and material layer 110 comprising a source 112 and a drain 114, for example. A transparent or semi transparent TFT, such as device 100, may provide advantages when utilized in optical applications, for example, although the
25 claimed subject matter is not so limited.

Formation of the one or more material layers of device 100 may comprise several process operations. As stated previously, a substrate, such as substrate 102, may have one or more materials applied to at least a portion of at least one surface of the substrate.

5 The one or more materials may be applied to a specified thickness, which may be a substantially uniform or substantially non-uniform thickness, and the thickness may depend at least in part on the type of material applied. For example, a liquid material may be applied to a desired wet film thickness, and may be selected based at least in part on tolerance for cracks when in a solidified state, for example. In one particular embodiment, 10 a precursor material, such as a liquid precursor, for example, may be applied to at least a portion of at least one surface of the substrate. In one embodiment, a liquid precursor may comprise a sol-gel, which may comprise a colloidal solution, for example, and may be applied by one or more deposition processes, such as spin coating, for example.

15 In this embodiment, the liquid precursor sol-gel may comprise a solution, such as a colloidal solution, where one or more materials are dissolved in a solvent, such as an alcohol solvent. Types of materials suspended within the solvent vary, but may include inorganic metal salts and/or organic metal compounds, such as metal oxides. For example, zinc isopropoxide, or zinc chloride may be employed. Alternatively, other 20 materials, such as compounds of zinc and/or other metals, and/or group VI elements of the period table (oxygen, sulfur, selenium, or tellurium, for example, oxide, sulfide, telluride, or selenide), may be employed; however, the claimed subject matter is not limited to these examples, of course.

Application of a liquid precursor may vary, but techniques including dipping, spraying, spin coating, vacuum deposition and/or spreading; however, again, the claimed subject matter is not limited to use of just these methods of application of a liquid precursor, and, additionally, the claimed subject matter is not limited to use of a liquid precursor.

After application of one or more materials, such as one or more precursors, to at least a portion of a substrate, at least a portion of the substrate and one or more material layer that have been applied may be annealed. Processes for annealing may vary, and may include oven annealing, rapid thermal processing (RTP), and/or laser annealing, for example. Any one of a number of annealing techniques may be applied to produce results, such as, without limitation, the techniques, described in, for example, Handbook of Thin Film Technology, Maissel, L. and Glang, R., available from McGraw-Hill, Inc., published 1970. Laser annealing, as may be employed in at least one embodiment, may be understood with reference to FIG. 2, below.

Illustrated in FIG. 2 is an embodiment 120 of a computer-controlled laser annealing system; however, laser annealing system embodiment 120 is merely one example of a system in accordance with the claimed subject matter. Many other system embodiments are possible and included within the scope of the claimed subject matter. This particular embodiment, however, 120, performs operations that may be implemented as software executing on a processor, hardware circuits, structures, or any combination thereof.

System 120 includes processing system 122, which may perform processing by interacting with and/or directing the actions of one or more components of laser annealing

system 120, to perform various operations, as described in more detail below. Although not illustrated in detail, processing system 122 may comprise at least one processor and one or more memory components, such as Random Access Memory (RAM), Synchronous Dynamic Random Access Memory (SDRAM), and/or Static Random Access Memory (SRAM), for example. System 120 may further comprise: one or more hard drives; one or more removable media memory components, such as floppy diskettes, compact disks (CDs), tape drives; a display, such as a monitor, for example, and/or a user interface device, which may include a keyboard, mouse, trackball, voice-recognition device, or any other device that permits a user to input information and receive information.

Laser annealing system 120 may also comprise a support platform 124, as illustrated in FIG. 1, on which a partially formed device 128 may be supported when undergoing one or more laser annealing processes, for example. Partially formed device 128, in at least one embodiment, may comprise a substrate with one or more layers formed thereon, such as device 100 of FIG. 1, for example, although the claimed subject matter is not so limited. Furthermore, in this particular embodiment, platform 124 may be coupled to a position controller 126, which may alternatively be at least partially embodied inside platform 124. (not shown) In operation, position controller 126 may receive instructions from one or more software programs contained in memory, such as a memory of processing system 122, for example, which may be executed by one or more processors of processing system 122. Position controller 126 may result in partially formed device 128 to adjust position, such as based at least in part on a two or three-dimensional coordinate system, depending at least in part on one or more software programs being executed, for example. Alternatively, position controller 126 may be capable of controlling the position and/or direction of laser 130 (not shown), such as the

angle of incidence, for example, or may control the relative positions of both platform 124 and laser 130 (not shown), for example.

Laser annealing system 120 further comprises a laser 130, which may be capable
5 of generating a laser beam 132 at a particular frequency in the electromagnetic spectrum and having suitable energy to provide intense localized or "spot" heating. Laser annealing system 120 may also comprise a laser controller 134 coupled to laser 130, and may be configured to control the fluence, duration, and/or width of laser beam 132 when produced by laser 130. Furthermore, a beam controller 138 may be configured to perform various
10 operations upon laser beam 132, including shaping the laser beam, changing the focal point, changing the frequency, changing the beam shape, and, perhaps, adjusting the direction and/or position of laser beam 132 within region 136 so that laser beam 132 can contact one or more points on partially formed device 128, although, as previously implied, depending on the embodiment, position controller 126 may, alternatively or in addition,
15 affect the direction and/or position of laser beam 132 by affecting laser 130.

Additionally, system 120 may further comprise one or more laser beam homogenizers, condensers and/or mirrors (not shown), and, additionally, laser beam 132 may be projected through a mask, a galvanometer, or may be projected onto a contact
20 mask (not shown), for example. One or more of these devices may be implemented as part of beam controller 138, for example, and may be implemented in order to modulate, direct, and/or control the laser beam.

Laser 130, laser controller 134, beam controller 138, and position controller 126
25 may, individually or in combination, be controlled by suitable instructions in a software

program that is stored and executed by processing system 122, for example. A laser suitable for use in system 120 may comprise one or more types of laser, and may have a particular wavelength, power, and/or method of operation. Laser 130 may comprise, for example, a stepped or pulsed laser, and/or may be capable of producing a continuous beam. For example, in one embodiment, the laser may comprise a homogenized excimer laser, fired at a frequency of 200 Hz, with a wavelength of 248 nanometers (nm), fluence of 60 mJ/cm² (millijoules per unit area in square centimeters) or 100 mJ/cm², and operated with pulse capability for 100-3000 pulses, for example. Table 1 also lists other types of lasers that may be suitable for use in a system such as system 120, although, these few examples are not intended to limit the scope of the claimed subject matter in any way.

Laser Type	Laser Material	Wavelength(s)
Excimer	Argon Fluoride	193nm
	Krypton Fluoride	248nm
	Xenon Chloride	308nm
	Xenon Fluoride	351nm
Gas	Krypton	476nm, 528nm
	Argon	488nm, 514nm
	Copper Vapor	510nm
	HeNe	633nm
	Carbon Dioxide	9600nm, 10,600nm
Solid State	Nd: YAG	355nm, 532nm, 1064nm
	Erbium	1504nm
Fiber	Ytterbium	1060-1120nm

Table 1

In operation, laser 130 may produce a continuous wave beam, or may be pulsed or Q-switched, for example, and the manner of operating laser 130 may depend on a variety of factors, such as at least in part the material comprising one or more layers, and/or the type of laser, for example. In one embodiment, laser 130 may be operated in a pulsed manner, in which the laser beam may be pulsed sequentially by being turned on relatively briefly, e.g. for 20 nanoseconds (ns), and then turned off, while the beam is stepped or scanned to other regions to be annealed, or may operate to apply multiple pulses to single region, for example.

After one or more such regions or portions absorb the energy, or laser flux, provided by a laser beam, one or more material properties may become altered. For example, if the laser irradiates an area of a layer of sol-gel, the sol-gel may solidify, and/or may become at least partially crystalline or densified, e.g., made more dense, and/or may be altered chemically, such as to an oxide, for example, and/or optically, such as with respect to transparency and/or refractive index, for example. The amount of energy supplied by the laser may determine at least in part the affect on the area which absorbs the energy, and the energy may be dependent on a variety factors including, at least in part, the wavelength of the laser, the frequency, the fluence of the beam, the focal point of the beam, and/or the method of operation of the beam, as just a few examples.

Additionally, the areas or regions annealed may be determined at least in part by adjusting one or more of these factors, such as, for example, selecting the focal point or wavelength such that a portion of a material layer below the surface of the layer is annealed, while the surface of the layer is not annealed.

Additionally, differing areas of device 128 may be subjected to differing amounts of energy by the laser, and this may allow device 128 to have varying material properties by selectively or "spot" annealing the material layer, resulting in selectively modifying material properties. As used herein, selectively, when used, such as with modifying material properties, for example, generally refers to modifying one or more portions of a material, such as by annealing, wherein the portions are selected based at least in part on the particular location of the one or more portions, such as with localized or spot annealing, for example. For example, portions of the device 128 may be annealed substantially uniformly, while other areas may not be substantially uniformly annealed. The laser may anneal a layer differently depending at least in part of the particular direction, such as the x, y, and z directions, for example, in a rectangular spatial coordinate system. This may result, for example, in forming a material layer with a concentration gradient of metal oxide through the layer, for example, or may result in the forming of a patterned layer of material, such as a patterned oxide layer, in which differing areas of a material layer have differing material properties, including varying conductivities, densities, optical properties and/or crystallinities, for example. This may allow the formation of a device, such as device 100, for example, without performing additional patterning processes. In this manner, a patterned material layer may be formed to have particular material properties at particular positions in the layer. Additionally, multiple material layers may be annealed during a laser annealing process, and differing portions of differing layers may be annealed selectively to form a device, such as a TFT, for example. The formation of a device with one or more material layers may be understood with reference to FIG. 3, below.

Referring now to FIG. 3, one embodiment of a technique for forming a thin film is illustrated by a flowchart, although, of course, the claimed subject matter is not limited in scope in this respect. Thus, such an embodiment may be employed to at least partially form a thin film, as described below. The flowchart illustrated in FIG. 3 may be used to form a device at least in part, such as device 100 of FIG. 1, for example, although the claimed subject matter is not limited in this respect. Likewise, the order in which the blocks are presented does not necessarily limit the claimed subject matter to any particular order. Likewise, intervening additional blocks not shown may be employed without departing from the scope of the claimed subject matter.

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Flowchart 150 depicted in FIG. 3 may, in alternative embodiments, be implemented in software, hardware and/or firmware, and may comprise discrete and/or continual operations. In this embodiment, at block 152, a material layer is formed on at least a portion of a substrate. At block 154, at least a portion of the material layer may be annealed, such as by "spot" annealing, for example. At block 156, at least a portion of the material layer may be washed. In at least one embodiment, one or more of the aforementioned operations may be repeated, such as to form a device with multiple material layers.

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Forming a material layer may comprise one or more deposition processes, where a material or combination of materials is applied to a portion of a substrate, again, as illustrated at block 152. In particular, in one embodiment, the substrate may comprise a non-conductive substrate of glass or plastic, for example. Likewise, a material may comprise a liquid or semi-liquid, such as a sol-gel, and may be applied by one or more deposition methods, including, spraying, dipping, vacuum deposition, spreading and/or

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spin coating, for example. The material may be applied to a substantially uniform thickness, or may be substantially non-uniform, as previously described. In at least one example embodiment, the material may comprise a sol-gel at least partially comprising zinc isopropoxide and 2 ethylhexanoic acid in an alcohol solvent or zinc chloride in an alcohol solvent, and may be applied by a spin coating process. The material may be applied to a particular thickness, such as a selected wet film thickness, as described previously.

Continuing with this embodiment, at block 154, at least a portion of the material layer applied at block 152 may be annealed. Although methods for annealing may vary, in this embodiment, a laser system, such as system 120 of FIG. 2, may be utilized to perform one or more annealing processes. In this embodiment, a substrate with one or more material layers may be provided to a laser system and the laser may be operated to anneal at least a portion of one or more layers. One or more layers may be uniformly annealed, annealed to differing degrees, or may be selectively annealed at particular “spots” or positions, in order to form a layer of material having varying material properties, for example. By modifying one or more properties of the laser, such as wavelength, frequency, fluence, and/or duration, for example, differing material properties may be imparted to different areas of one or more material layers, such as differing degrees of crystallinity or consolidation. For example, in the example embodiment noted previously, a layer of sol-gel comprising zinc chloride in an alcohol solvent may be selectively annealed, forming regions of conductive zinc oxide in a material layer, for example. In this manner, a device, such as device 100 of FIG. 1, may be formed, and the resultant thin film transistor may be formed without performing additional patterning processes, for example.

Alternatively, multiple material layers may be formed on the substrate prior to performing one or more annealing processes.

In this embodiment, moving to block 156, at least a portion of one or more material
5 layers may be washed, and, in this embodiment, washing may result in the removal of one or more portions of the one or more layers. For example, if a material layer is selectively annealed at block 154, a portion of the layer not annealed may not be solidified, and may be removable by a wash. This may result in the forming of regions of exposed solidified material on a device, which may be further processed, such as by having other materials
10 layered on the solidified portions, for example. In this manner, thin film electronic devices, such as thin film transistors, capacitors, resistors, photovoltaic cells and/or resistors, for example, may be formed.

It is, of course, now appreciated, based at least in part on the foregoing disclosure,
15 that software may be produced capable of performing one or more of the foregoing operations, such as forming one or more material layers, and annealing at least a portion of the one or more layers. It will, of course, also be understood that, although particular embodiments have just been described, the claimed subject matter is not limited in scope to a particular embodiment or implementation. For example, one embodiment may be in
20 hardware, such as implemented to operate on a device or combination of devices as previously described, for example, whereas another embodiment may be in software. Likewise, an embodiment may be implemented in firmware, or as any combination of hardware, software, and/or firmware, for example. Additionally, all or a portion of one embodiment may be implemented to operate partially in one device, such as a laser
25 device, and partially in a computing device, for example. Likewise, although the claimed

subject matter is not limited in scope in this respect, one embodiment may comprise one or more articles, such as a storage medium or storage media. This storage media, such as, one or more CD-ROMs and/or disks, for example, may have stored thereon instructions, that when executed by a system, such as a computer system, computing platform, or other system, for example, may result in an embodiment of a method in accordance with the claimed subject matter being executed, such as one of the embodiments previously described, for example. As one potential example, a computing platform may include one or more processing units or processors, one or more input/output devices, such as a display, a keyboard and/or a mouse, and/or one or more memories, such as static random access memory, dynamic random access memory, flash memory, and/or a hard drive, although, again, the claimed subject matter is not limited in scope to this example.

In the preceding description, various aspects of the claimed subject matter have been described. For purposes of explanation, specific numbers, systems and/or configurations were set forth to provide a thorough understanding of the claimed subject matter. However, it should be apparent to one skilled in the art having the benefit of this disclosure that the claimed subject matter may be practiced without the specific details. In other instances, well-known features were omitted and/or simplified so as not to obscure the claimed subject matter. While certain features have been illustrated and/or described herein, many modifications, substitutions, changes and/or equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and/or changes as fall within the true spirit of the claimed subject matter.